FOURTH QUARTERLY REPORT

Date of Report: *October 15, 2005*

Contract Number: *DTRS56-04-T-0002>*

Prepared for: *DOT, PRCI, SoCal Gas, Gaz de France, and Valero Energy*

Project Title: *Determining Integrity Reassessment Intervals through Corrosion Rate Modeling and Monitoring*

Prepared by: *Southwest Research Institute*

For quarterly period ending: *October 1, 2005*

Table 1. Activities and Milestone Status Summary

Activity #	Task #	Activity/Milestone	Expected Date	Status
16	3.3	Obtain field data on external corrosion and compare to model predictions	8/16/2005	Awaiting input from companies that have been contacted
17	4.2	Obtain field data from pipeline companies	8/26/2005	Awaiting input from companies that have been contacted
18	3.2	Experimental determination of CP shielding, chemistry, and corrosion rate under disbonded coating	9/06/2005	Completed
19	5.1	Presentation of methodology and results at a public workshop in Washington, DC	9/16/2005	Completed

TECHNICAL STATUS

COMPUTER MODELING OF DISBONDED COATING CORROSION RATES/CHEMISTRY

Accomplishments

(1) In 2D geometry, the effect of flow on the crevice corrosion rate of pipeline due to O_2 transport was completed and compared to experimental results
(2) Crevice corrosion due to CO_2 and O_2, in a 12 component system including complexes, carbonate and bicarbonate species has been completed.
(3) Internal corrosion due to O_2 and CO_2 with consideration of ionic transport has been completed.

(4) The modeling results have been submitted in the form of two papers to the NACE Corrosion/2006 conference

Problems

Many operational problems were encountered in the experimental investigation of disbonded coating environment under flowing conditions. Many of these problems were solved, but some remain due to the complexity of the design. These difficulties translated to less than perfect fit between experiments and modeling.

Results

One of the common occurrences of external corrosion is the flow of groundwater through a holiday in the coating in to a disbonded area, the water exiting through another holiday located elsewhere in the coating. In a spiral-wrapped tape coating, the flow can occur all around the pipe at the overlap between wraps. The disbonded coating modeling and experiments published in the literature have not involved flow of solution through the disbonded region. Therefore, experimental apparatus was constructed to determine the effect of controlled flow and compare to model predictions. The overall view of the apparatus is shown in Figure 1.

Figure 1. Overall view of the experimental apparatus. The data acquisition system is not shown in this picture.

Among the three tests conducted so far, the first two had complications due to defective initial design (first test) and solution leakage (second test). For the third test, the test cell was modified and the test was more carefully conducted although problems still existed. Compared to the first two tests, experimental data generated from this third test is more reasonable. The Test 3 data is analyzed below.

In Test 3, many parameters were measured including steel potential, pH, relative O_2 content in the disbonded region, and current flow from the coupons to the steel plate. The potential distribution inside the disbondment appears to be relatively uniform (Figure 2). However, since the reference electrodes and pH electrodes were located in the disbondment some distance from the holiday the gradient in the potential at the mouth of the disbondment is not apparent in Figure 2. The potential in the holiday area was maintained close to -0.85V vs. $Cu/CuSO_4$.

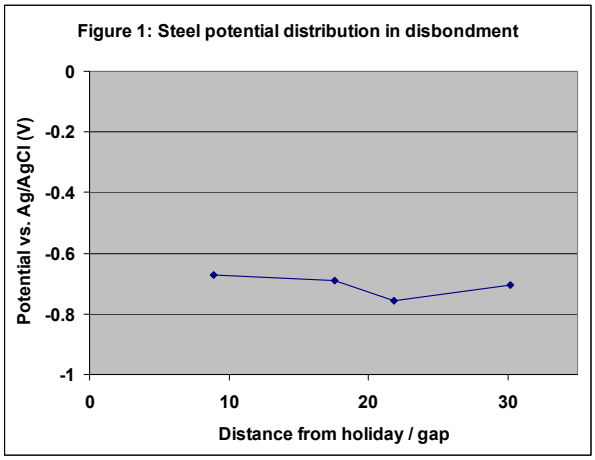


Figure 2. Potential distribution inside the disbondment

Since it was found after the test that the platinum tips being used to measure O_2 content was covered by corrosion product (Figure 3, upper holes in brown color), it is unclear how well the measured data are. Figure 4 seems to indicate that the O_2 content is smaller near the holiday than in the disbondment due to the change of Pt potential. This may be understandable because at the holiday, the cathodic polarization consumes the oxygen rapidly, whereas the potential inside the disbondment is not sufficient to consume oxygen as rapidly.

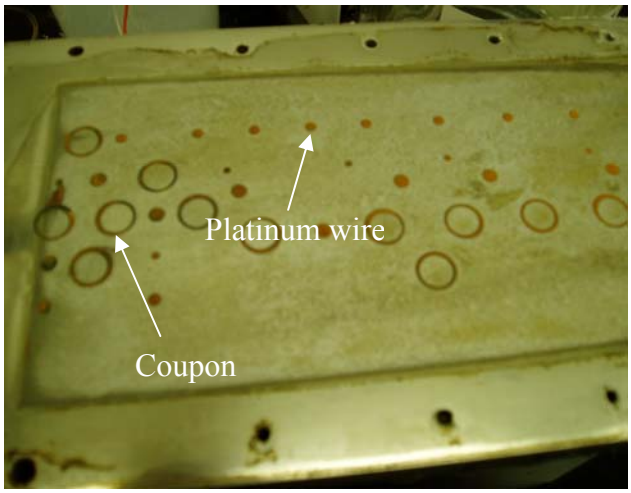


Figure 3: Coupons and steel plate experienced corrosion in disbondment after slight polish.

The few parameters measured that are relatively robust include the O_2 concentration in the bulk solution (inlet, 0.21 atm) and at the outlet of the disbondment (0.02 atm), and the measured current flowing from coupons (the discs in the steel plate in Figure 2) to the steel plate (Figure 5). The solution pHs at the inlet and at the outlet are measured which roughly 4.7 inlet and 5.4 outlet. The conductivity of the solution at the outlet (300 micro siemens/cm) is slightly larger than at the inlet (250 micro siemens/cm).

The experimental results were simulated through modeling using boundary conditions consistent with test parameters: inlet and outlet pHs (average taken 4), inlet (0.21 atm) and outlet O_2 concentration (0.02 atm), and conductivity (30 ohm m). The simulated flowing currents between coupons and steel plate (Figure 5) are compared to experimentally measured results. There are discrepancies in the actual values of the current, although the shapes of the curves look similar. It is unclear why there are two

maximum currents in the measured data. The current should be zero far into the disbondment as shown in the simulated diagram because no CP flows into this region. These results and the inconsistencies in the measured data point to the fact that the experimental apparatus should be simplified and improved considerably.

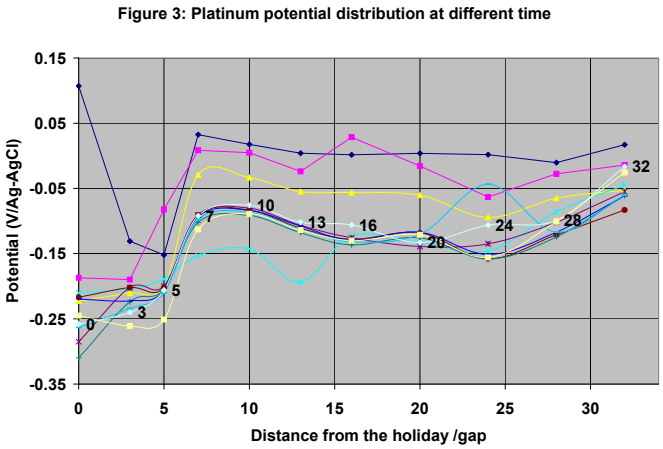
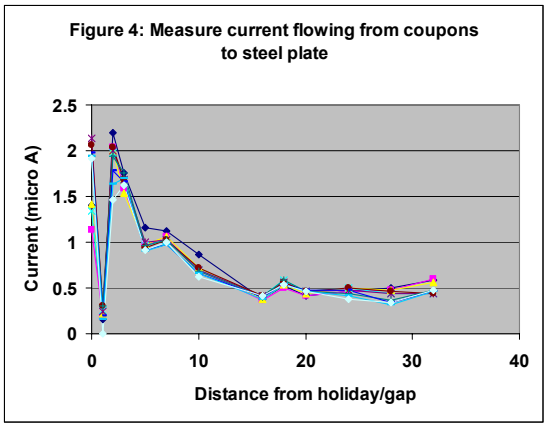


Figure 4. Potential of Pt electrodes which is sensitive to a combination of pH and dissolved oxygen



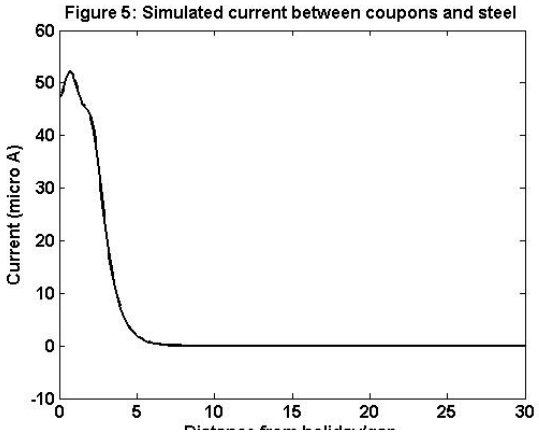


Figure 5. Experiments vs. model results on current distribution in disbondment

Future Work:

(1) Summarize the above work and write down to record the findings;
(2) Seek methods to simplify the models. These simplified models are hoped to be used conveniently by operators or they can be considered to be implemented into the NACE ICDA and ECDA standards;
(3) Obtain field data to correlate with modeling

BUSINESS STATUS

- The DOT portion of the funding has been expended slightly over 90 percent. The PRCI cash co-funding has been expended in the development and validation of the MAS probe.

SCHEDULE

Several tasks are in progress and are on schedule. Field data gathering is behind schedule and will be accelerated in the next reporting period. Discussions were held with co-funding organizations on obtaining field data.

PAYABLE MILESTONES

1. Public presentation
2. Fourth quarterly report

ISSUES, PROBLEMS OR CHALLENGES

These have been mentioned in the different tasks.

PLANNED ACTIVITIES IN THE NEXT 30 TO 60 DAYS

- Obtain field data from co-fundng organizations
- Further examine experimental results and seek ways to use literature data to validate model

PUBLIC PAGE

One of the factors important in determining the reassessment interval is the corrosion rate. Both external and internal corrosion rates are affected by a number of conditions. The objective of this project is to use mechanistic modeling to generate simplified guidelines for estimating external and internal corrosion rates. A need for such a model-based estimation is especially important for corrosion under shielded, disbonded coatings.

Significant progress has been made in modeling the corrosion rate under shielded, disbonded coatings for both static and low-flow conditions (low flow assumed for external corrosion is reasonable under most circumstances where pin-hole leaks in coatings can lead to slow flow of groundwater through the disbonded area). It is shown that with the diffusion of oxygen through the coating holiday, flow conditions can significantly increase the corrosion rate near the mouth of the disbondment. Validation is being performed using specially designed experimental apparatus. Partial validation of the trend in the corrosion current has been found. The limitations of the experimental data generated to date prevent further validation. Validation using field data will be performed in the future.